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Diversity and seasonality of frugivorous butterflies (Lepidoptera, Nymphalidae) in the Tapajós National Forest, Pará, Brazil

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ABSTRACT

The diversity and seasonality of fruit-feeding butterflies was evaluated during one year in the Tapajós National Forest. Traps, type Van Someren-Rydon, were used for collecting and the following parameters were evaluated: abundance, richness, Shannon diversity (H') and evenness (E') indices and Berger-Parker dominance index (BP). Circular analyzes of abundance and the correlation between monthly precipitation and richness and abundance were performed. A total of 834 specimens, distributed in 67 species, were collected. In the period of less rain, 643 specimens of 64 species, H'= 3.33, E' = 0.80 and BP= 0.10 were identified. Greater abundance and richness were found in the period of less rainfall, between the months of June and August, according to correlations and circular analysis.

Keywords: Brazilian Amazon; Papilionoidea; Protected Area.

Diversidade e sazonalidade de borboletas frugívoras (Lepidoptera, Nymphalidae) na Floresta Nacional do Tapajós, Pará, Brasil

RESUMO

Buscou-se avaliar a sazonalidade e a diversidade de borboletas frugívoras, no decorrer de um ano na Floresta Nacional do Tapajós, a fim de verificar se há alterações na fauna de borboletas ao longo deste período. Na captura utilizaram-se armadilhas Van Someren-Rydon e foram avaliados os parâmetros: abundância, riqueza, índices de diversidade (H') e uniformidade (E') de Shannon e índice de dominância de Berger-Parker (BP). Foram realizadas análises circulares de abundância e a correlação entre a precipitação mensal e riqueza e abundância. Foi encontrado um total de 834 espécimes distribuídos em 67 espécies. No período de menos chuva encontrou-se 643 espécimes de 64 espécies, H'= 3,33, E'= 0,80 e BP= 0,10. Maior abundância e riqueza foram encontradas no período de menos chuva entre os meses de junho a agosto.

Palavras-chave: Amazônia Brasileira, Papilionoidea, Unidade de Conservação.

Introduction

In much of the tropical region, a period with more rain alternates with a dry (or drier) period. These changes in rainfall configure seasonal patterns in the production of food resources (leaves, flowers and fruits) for insects and other animals. Herbivores that feed only on new leaves, or on nectar, experiment a highly seasonal environment in such circumstances, due to variations in the availability of their food resources (WOLDA, 1988). Seasonal variations in the Amazon region are caused mainly by rainfall, which is the most important climatological variable dividing the year into two periods, more and less rain (MORAES et al., 2005).

Butterflies are widely used as models in biology and ecology studies because they are relatively large and easy to capture and their taxonomy is well resolved (RIBEIRO et al., 2010). Among these is the guild of fruit-feeding butterflies, which includes the Nymphalidae of the satyroid line: Satyrinae, Charaxinae, Biblidinae and some Nymphalinae (DUARTE et al., 2012). These insects feed on fermenting fruit, decomposing animals, excrements and plant exudates. In tropical forests, fruit-feeding butterflies may represent between 40-55% of the total nymphalid richness (BROWN Jr., 2005). They are easy to collect using traps that contain fermented fruit bait, enabling simultaneous and standardized sampling in different environments and months (UEHARA-PRADO et al., 2005), which is ideal for ecological and comparative studies.

Tropical forests are the richest biomes on earth in terms of biodiversity. It is estimated that about 50% of all species live in these forests, which are also among the most threatened biomes (FONSECA; SILVA, 2005). In the Brazilian portion of the Amazon, for example, there are 1,800 species of butterflies, representing about 24% of the overall diversity of the group (OVERAL, 2001). The Amazon is the largest rainforest area in the world and almost 50% of it is in Brazil (FONSECA; SILVA, 2005). However, this forest is under human pressure, especially in its eastern portions (BENSUSAN, 2005). The main risks to biodiversity there are logging, deforestation, fires, fragmentation, mining, extinction of local fauna, invasion of exotic species, wildlife trade and climatic changes (FEARNSIDE, 2003).

In an effort to increase environmental conservation, the Brazilian government has created numerous conservation units since 1970 (CASES, 2012). One of these conservation units founded by the government is the Tapajós National Forest (FLONA do Tapajós), created in 1974 (PADOVAN, 2004) as a sustainable use conservation unit (BENSUSAN, 2005). In this work we aimed to investigate changes in the composition, diversity, abundance and seasonality of fruit-feeding butterflies during one year in the Tapajós National Forest, to ascertain if rainfall affects the distribution of these insects.

Materials and Methods

The Tapajós National Forest (FLONA do Tapajós) (20º 45'S; 55° 00'W) (Figure 1) is located in the western portion of the state of Pará. It has an area of 527,319 ha, including the municipalities of Belterra, Aveiro, Rurópolis and Placas (BRASIL, 2012). The climate there, according to Köopen's classification, is characterized as Ami, i.e. tropical humid with average annual temperature of about 25 ° C; a rainy season between December and May; and a less rainy season from June to November (MORAES et al., 2005). During the sampling period, the total recorded rainfall was 1343.8 mm; during the period when there was more rain, 1009.3 mm, and in the period of less rainfall, 334.5 mm. These data were obtained data from the Belterra Meteorological Station of the National Institute of Meteorology (INMET). The vegetation is terra-firme Ombrophilous Dense Forest with canopy height between 30 and 40 m, with some emergent trees reaching up to 50 m (HENRIQUES et al., 2008).

The study areas are located at km 83 of highway BR-163 (Santarém-Cuiabá direction), in the municipality of Belterra. Area 1 (A1 is at 03º 00'25"S; 54° 58'35"W) and area 2 (A2 at 03º 03' 58.9"S; 54° 58 '22.1"W) (Figure 1). The distance between the two areas is approximately 6.5 km.

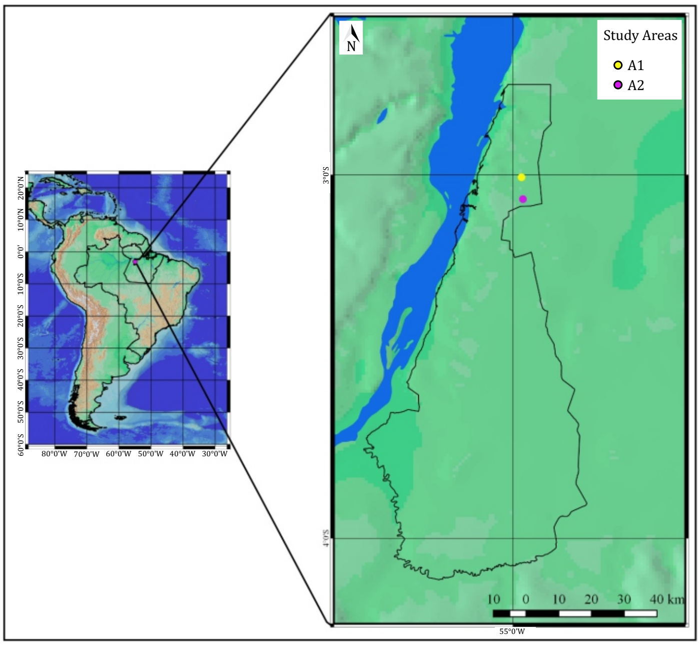


Figure 1. Geographic limits of FLONA do Tapajós in Pará state, Brazil, and study areas. / **Figura 1.** Limites geográficos da FLONA do Tapajós, Pará, Brasil e áreas do estudo.

Each area received two sampling units (UA). Each was composed of five traps type Van Someren-Rydon (UEHARA-PRADO et al., 2005), baited with banana and cane juice fermented for 48 hours, arranged 20 meters apart from one another and suspended at 1.5 to 1.6 meters from the ground.

Monthly sampling was carried out from December 2011 to November 2012, totaling 580 hours a month, and 2,960 total hours per sampled area. The traps stayed open simultaneously for five consecutive days, and were inspected every 24 hours. All subjects captured were collected.

Specimens were sorted and mounted at the Laboratório de Estudos de Lepidópteros Neotropicais (LELN) of the Universidade Federal do Oeste do Pará (UFOPA), where the material was stored in dry envelopes and / or on entomological pins. The voucher material was incorporated into the LELN collection. Species identification was carried out using specialized literature and web sites (UEHARA-PRADO et al., 2004; WARREN et al., 2016). Experts in the group were also consulted. The nomenclature and systematic ranks of the group followed Lamas (2004).

To compare the diversity of butterflies between the more and less rainy periods, the following parameters were used: richness (S), abundance (N), Shannon diversity (H') and evenness (E') indices, and Berger -Parker (BP) dominance (MAGURRAN, 2011). The H 'values obtained in the periods of more rain and less rain were compared using the "t" Student test. The influence of monthly precipitation over abundance (N) and richness (S) was evaluated using Pearson's correlation. All calculations were carried out in PAST 2:06 (HAMMER et al., 2001).

In order to verify seasonality, circular analyzes were carried out for the entire community and taxonomic groups (subfamilies), using the abundance data plotted in circular histograms distributed over the 360°. In this analysis, the month of capture of each specimen was transformed in degrees and the mean vector (μ) and its length (r) were calculated (ZAR, 2010). The mean vector length varies from zero to one and describes how butterflies concentrated throughout the year. Zero indicates that butterfly occurrence was the same every month, whereas one indicates that all butterflies occurred on a single month of the year (RIBEIRO et al., 2010).

To test the null hypothesis that butterflies are distributed evenly throughout the year, the Rao test (U) was carried out. We chose this test because it is less sensitive to polymodal data (BERGIN, 1991). Tests and histograms were prepared in a trial of the program Oriana 3:21 (KOVACH, 2010).

Results

We collected 834 specimens (N) in 67 species (S). Biblidinae was the most abundant subfamily, followed by Morphinae, Satyrinae, Charaxinae and Nymphalinae (Table 1). In the less rainy period (Table 2), the highest values of abundance (N= 643) richness (S= 64) and Shannon diversity (H'= 3.33) were found. June had the highest richness (S= 40) (Figure 2) and abundance (N= 156) (Figure 3). In the rainy season, these values were lower (Table 2): abundance (N= 191), richness (S= 37) and Shannon diversity (H'= 2.90). The highest richness (S= 29) (Figure 2) and abundance (N= 106) (Figure 3) were found in May. Shannon Uniformity (E'= 0.80) was the same in both periods. In the comparison between diversity (H') indices, the "t" test showed a significant statistical difference between the periods of more and less rain (t= 5.015).

Abundance was moderately (though not significantly) negatively correlated with precipitation (-0.502; p= 0.096). Richness also presented moderate negative correlation with rainfall, which was significant at the 5% level (-0.625; p= 0.029).

Circular analysis (Table 3) showed that the total butterfly assembly and that assembly divided into subfamilies (Figures 4-9) were not evenly distributed throughout the year. The mean vector (μ) for the total yield and for each subfamily was between 187 and 236 (June - August). The subfamily Satyrinae was more abundant in June (average vector length r= 0.576). Consequently, 48.3% of abundance and 77.6% of the richness were concentrated from June to August (during the period of less rain).

Of the 67 species, 48 (71.6%) were represented by less than ten specimens. *Nessaea obrinus obrinus* (Linnaeus, 1758) was the most abundant (N= 103) (Table 1).

Regarding species composition, 30 species occurred only in the period of less rain and only three were unique to the period of more rain (Table 1), which is reflected in the large difference in species richness from one period to another (Table 2).

Table 1. Composition and abundance of fruit-feeding butterflies collected with trap Van Someren-Rydon in the FLONA do Tapajós, Pará, Brazil, during the period from December 2011 to November 2012. / **Tabela 1.** Composição e abundância de borboletas frugívoras coletadas com armadilha Van Someren-Rydon na FLONA do Tapajós, Pará, Brasil, durante o período de dezembro de 2011 a novembro de 2012.

Subfamily / Species and Subspecies	2011	2012											TOTAL
	D	J	F	M	A	M	J	J	A	S	O	N	
Biblidinae	**1**	**1**	**7**	**18**	**17**	**21**	**28**	**43**	**26**	**18**	**25**	**22**	**227**
Catonephele acontius acontius (Linnaeus, 1771)					2	5	5	3	6	1	4	3	29
Ectima iona (Doubleday, 1848)									1				1
Hamadryas arinome arinome (Lucas, 1853)					1			7	4	7	10	6	35
Hamadryas chloe obidona (Fruhstorfer, 1914)			6	4	2	5	7	10	2	2	5	2	45
Hamadryas velutina velutina (H. W. Bates, 1865)							1	2	1			1	5
Myscelia orsis (Drury, 1782)				1		1	1	2		2		1	8
Nessaea obrinus obrinus (Linnaeus, 1758)	1	1	1	13	12	10	14	19	12	6	6	8	103
Temenis laothoe laothoe (Cramer, 1777)												1	1
Charaxinae	**0**	**0**	**3**	**5**	**7**	**18**	**31**	**17**	**9**	**15**	**16**	**24**	**145**
Agrias amydon phalcidon (Hewitson, 1855)										1			1
Agrias claudina claudina (Godart, 1824)								1					1

Cont.

Subfamily / Species and Subspecies	2011	2012											TOTAL
	D	J	F	M	A	M	J	J	A	S	O	N	
Agrias narcissus tapajonus Fassl, 1921											1	1	2
Archaeoprepona amphimachus amphimachus (Fabricius, 1775)				1			1	1			1	2	6
Archaeoprepona demophon demophon (Linnaeus, 1758)			3	2	3	12	17	7	5	6	8	8	71
Archaeoprepona demophoon demophoon (Hübner, 1814)											1	3	4
Archaeoprepona licomedes licomedes (Cramer, 1777)					1	3	1	1				1	7
Archaeoprepona meander meander (Cramer, 1775)				2			1				1	3	7
Hypna clytemnestra clytemnestra (Cramer, 1777)								1					1
Memphis acidalia acidalia (Hübner, 1819)					2							1	3
Memphis basilia basilia (Stoll, 1780)							1						1
Memphis grandis (H. Druce, 1877)						1	1	1		1			4
Memphis leonida leonida (Stoll, 1782)									1				1
Memphis moruus morpheus (Staudinger, 1886)							2				1		3
Memphis philumena philumena (Doubleday, 1849)									1				1
Memphis polycarmes (Fabricius, 1775)						1				1	1		3
Prepona dexamenus dexamenus (Hopffer, 1874)							1						1
Prepona pheridamas (Cramer, 1777)						1	3	2		4	1	2	13
Prepona pylene eugenes (H.W. Bates, 1865)											1		1
Zaretis isidora (Cramer, 1779)							1	2	1	1		3	8
Zaretis itys itys (Cramer, 1777)					1		2	1	1	1			6
Morphinae	**1**	**0**	**0**	**0**	**0**	**18**	**32**	**33**	**28**	**20**	**18**	**29**	**179**
Bia actorion actorion (Linnaeus, 1763)						4	4	8	6	2	3	6	33
Caligo euphorbus euphorbus (C. Felder & R. Felder, 1862)						1							1
Caligo eurilochus eurilochus (Cramer, 1775)							1					1	2
Caligo idomeneus rhoetus (Staudinger, 1886)						1			1				2
Caligopsis seleucida juruana (Fruhstorfer, 1912)								1					1
Catoblepia berecynthia berecynthia (Cramer, 1777)						2	1	1			2	2	8
Catoblepia soranus (Westwood, 1851)	1					1	3			1	3	1	10
Catoblepia versintincta mossi (Bristow, 1981)						3			7	3	1	1	15
Catoblepia xanthicles sosigenes (Fruhstorfer, 1913)										1			1
Morpho achilles achilles (Linnaeus, 1758)						1	2	3	2	3	1	2	14
Morpho deidamia deidamia (Hübner, 1819)						1	1	3	2	1	2	1	11
Morpho helenor helenor (Cramer, 1776)						3	18	17	7	6	6	13	70
Morpho menelaus menelaus (Linnaeus, 1758)						1	1					1	3
Morpho rethenor rethenor (Cramer, 1775)										1			1
Opsiphanes quiteria quiteria (Stoll, 1780)							1		3	2		1	7
Nymphalinae	**2**	**0**	**0**	**2**	**3**	**19**	**22**	**17**	**27**	**5**	**6**	**19**	**122**
Colobura annulata (Willmott, Constantino & Hall, 2001)							2	1				2	5
Colobura dirce dirce (Linnaeus, 1758)				1		5	12	7	7		1	8	41
Tigridia acesta tapajona (Butler, 1873)	2			1	3	14	8	9	20	5	5	9	76
Satyrinae	**0**	**0**	**4**	**6**	**8**	**30**	**43**	**34**	**13**	**4**	**4**	**15**	**161**
Caeruleuptychia caerulea (Butler, 1869)					1								1
Chloreuptychia agatha (Butler, 1867)				2			1	1					4
Chloreuptychia arnaca (Fabricius, 1776)							1						1
Chloreuptychia herseis (Godart, 1824)							2						2
Chloreuptychia hewitsonii (Butler, 1867)											1	1	2
Cissia terrestris (Butler, 1867)						1							1
Erichthodes antonina (C. Felder & R. Felder, 1867)												1	1
Haetera piera (Linnaeus, 1758)							1						1
Magneuptychia tricolor tricolor (Hewitson, 1850)						1	1	1	2				5
Megeuptychia antonoe (Cramer, 1775)						1	1						2
Pareuptychia ocirrhoe ocirrhoe (Fabricius, 1776)					1	6	2		1				10
Taygetis cleopatra (C. Felder & R. Felder, 1867)			1		1	1	5	4	1	1	1		15
Taygetis echo echo (Cramer, 1775)					1		2	2	1			1	7
Taygetis laches laches (Fabricius, 1793)			2	1	2	12	15	14	3	1	1	4	55
Taygetis mermeria mermeria (Cramer, 1776)								1					1
Taygetis sosis (Hopffer, 1874)				2	1	4	4	4	1	1		2	19
Taygetis thamyra (Cramer, 1779)			1	1	1	4	8	6	2	1		3	27
Taygetis virgilia (Cramer, 1776)									2			1	3
Taygetis sp.							1				1		2
Satyrinae sp.												2	2
Abundance	**4**	**1**	**14**	**31**	**35**	**106**	**156**	**144**	**103**	**62**	**69**	**109**	**834**

Table 2. Richness (S), abundance (N), Shannon diversity index (H')*, uniformity Shannon (E') and dominance of Berger-Parker (BP) of frugivorous butterflies collected with Van Someren-Rydon trap during periods of more and less rain and the total in the FLONA do Tapajós, Pará, Brazil, from December 2011 to November 2012. / **Tabela 2**. Riqueza (S), abundância (N), índice de diversidade de Shannon (H')*, uniformidade de Shannon (E') e dominância de Berger-Parker (BP) de borboletas frugívoras coletadas com armadilha Van Someren-Rydon nos períodos de mais e menos chuva e total na FLONA do Tapajós, Pará, Brasil, de dezembro de 2011 a novembro de 2012.

PARAMETER	+ RAIN	- RAIN	TOTAL
S	37	64	67
N	191	643	834
H'	2.90[t]	3.33[t]	3.31
E'	0.80	0.80	0.79
BP	0.20	0.10	0.12

* (Natural logarithm); t = significant at the 5% level by "t" test

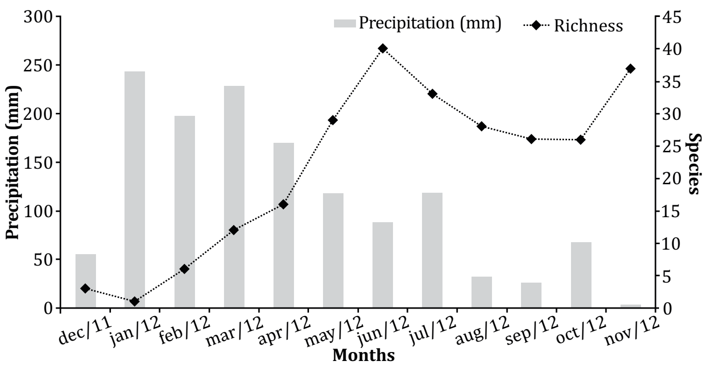


Figure 2. Temporal variation of species richness of frugivorous butterflies collected with Van Someren-Rydon trap in the FLONA do Tapajós, in Pará state, Brazil, with precipitation for the months of December 2011 to November 2012. / **Figura 2.** Variação temporal da riqueza das espécies de borboletas frugívoras coletadas com armadilha Van Someren-Rydon na Floresta Nacional do Tapajós, Pará, Brasil, com a precipitação para os meses de dezembro de 2011 a novembro de 2012.

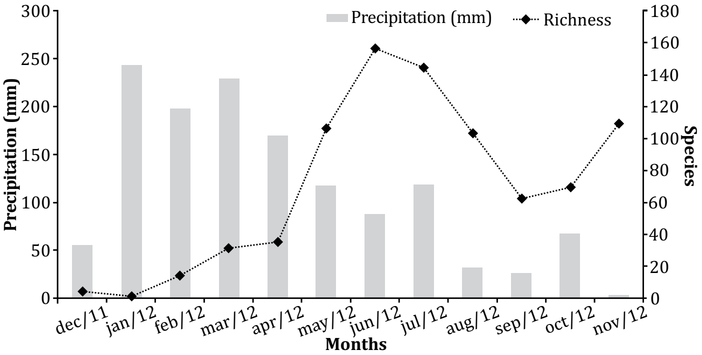
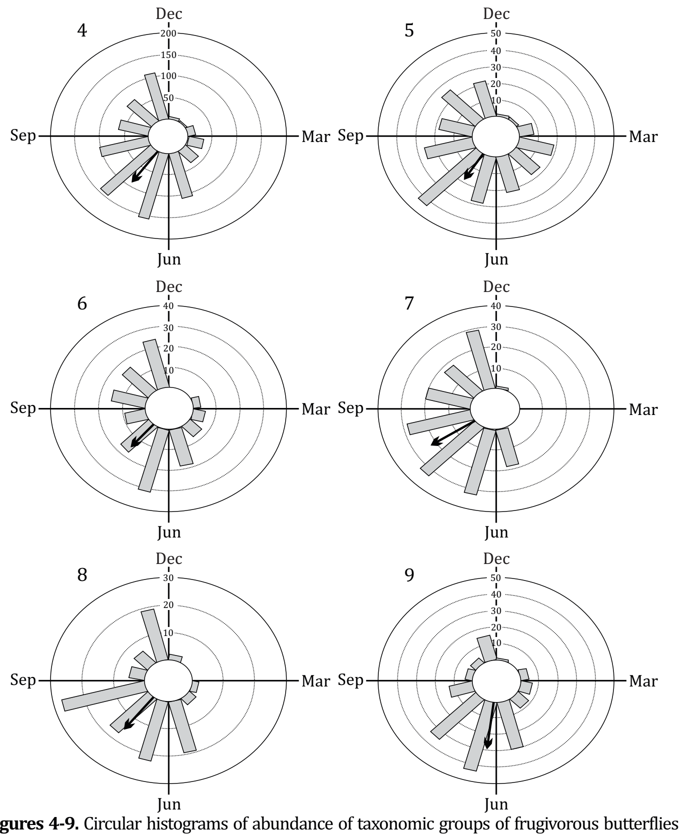


Figure 3. Temporal variation of species abundance of frugivorous butterflies collected with Van Someren-Rydon trap in the FLONA do Tapajós, in Pará state, Brazil, with precipitation for the months of December 2011 to November 2012. / **Figura 3**. Variação temporal da abundância das espécies de borboletas frugívoras coletadas com armadilha Van Someren-Rydon na Floresta Nacional do Tapajós, Pará, Brasil, com a precipitação para os meses de dezembro de 2011 a novembro de 2012.

Table 3. Circular analysis and Rao test (U) for the total community and subfamilies of frugivorous butterflies collected with trap Van Someren-Rydon in the FLONA do Tapajós, Pará, Brazil, from December 2011 to November 2012. µ = mean vector; r = vector length. / **Tabela 3.** Análises circulares e teste de Rao (U) para a comunidade total e subfamílias de borboletas frugívoras coletadas com armadilha Van Someren-Rydon na FLONA do Tapajós, Pará, Brasil, de dezembro de 2011 a novembro de 2012. µ = vetor médio; r = comprimento do vetor.

	µ	Month	r	U	P
Community	214.99	July	0.440	354.82	< 0.01
Biblidinae	213.42	July	0.359	340.97	< 0.01
Charaxinae	221.47	July - August	0.359	335.17	< 0.01
Morphinae	236.07	August	0.551	343.91	< 0.01
Nymphalinae	218.74	July	0.491	330.49	< 0.01
Satyrinae	187.33	June	0.576	330.49	< 0.01



Figures 4-9. Circular histograms of abundance of taxonomic groups of frugivorous butterflies collected with trap Van Someren-Rydon in the FLONA do Tapajós, in Pará state, Brazil, between the months of December 2011 to November 2012. **4**) Community, **5**) Biblidinae, **6**) Charaxinae, **7**) Morphinae, **8**) Nymphalinae and **9**) Satyrinae. The arrows represent the mean vector (µ). December is represented by 0º and the following months are represented in 30º intervals clockwise. / **Figuras 4-9.** Histogramas circulares de abundância de grupos taxonômicos de borboletas frugívoras coletadas com armadilha Van Someren-Rydon na Floresta Nacional do Tapajós, Pará, Brasil, entre os meses de dezembro de 2011 a novembro de 2012. **4**) Comunidade total, **5**) Biblidinae, **6**) Charaxinae, **7**) Morphinae, **8**) Nymphalinae e **9**) Satyrinae. As setas representam o vetor médio (µ). Dezembro está representado pelo 0º e os meses seguintes estão representados em intervalos de 30º em sentido horário.

Discussion

The period with less rain had the highest values of abundance (N), with 77.1% of the total richness (S) 95.5% and diversity (H'). The difference between the period of less and more rain (Table 2) was statistically significant, showing that the seasonality of the area influenced its diversity. This is consistent with other studies in the eastern Brazilian Amazon involving other groups of Lepidoptera (TESTON et al., 2012; DELFINA; TESTON, 2013; ALMEIDA et al., 2014). The variations in these parameters are associated with rainfall. In our data, during the period of less rain, precipitation was three times lower (334.5 mm) than during the period of more rain (1009.3 mm) (Figures 2 and 3), and this was confirmed by a moderate negative correlation between precipitation, abundance and richness.

Circular analysis also reinforced the idea that there is seasonality, since it points to the months of June to August (period of less rain). However, our result on seasonality contrasted with the findings of De Vries et al. (1997) in Ecuador, where during the less rainy months there was a decrease in the abundance and species richness of frugivorous butterflies. Barlow et al. (2007), on the other hand, in a study at the eastern Amazon, found a greater abundance and richness in the less rainy period, similar to what we have found. However, they noted that more studies should be carried out to correctly ascertain seasonality in the area.

There was a great number of species with few specimens (Table 1). This was expected since it is a trend in tropical forests (HALFFTER; MORENO, 2005), and had also been previously observed for frugivorous butterflies in Brazil, in the western (RAMOS, 2000; RIBEIRO; FREITAS, 2012), and eastern Amazon (BARLOW et al., 2007), Belize (LEWIS, 2001) and Malaysia (DUMBRELL; HILL, 2005).

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